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A Novel Approach for a Hostile Arms Fire Sensor

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ABSTRACT

A novel approach to sensing hostile arms fire has been developed at the US Army Research Laboratory (ARL). Utilizing the multispectral properties of the electromagnetic spectrum the sensor methodology has been tested very successfully in detecting point of origin of various types of arms fire. In-theatre travel in caravans has drawn enemy fire and urban settings have sometimes made it difficult to discern point of origin. This new multispectral methodology may overcome false alarm problems that can plague other types of sensors. Recently, the US Army Tank-Automotive Research, Development, and Engineering Command (TARDEC) is investigating the integration of the new sensor type for its military demonstration vehicle with on-board display systems. The integration approach will complement the existing sensory system for threat detection, while managing the power demand on the vehicle and data overload on the soldier.

Introduction

In Iraq combat operations, a considerable amount of fatalities were due to Rocket Propelled Grenades (RPG's)[1]. Responding to and suppressing fire requires the shooters be detected and located. Unfortunately, no single wavelength band of the electromagnetic (EM) spectrum offers a viable solution.

Can multispectral Electro-Optic/Infrared (EO/IR) sensors be utilized to detect and locate threats? What are size, weight, and power approximations for such a system and what significant integration parameters exist? Can methodology be augmented to incorporate the effects of environmental conditions and atmospheric spectral transmission in the sensor?

In addition to these questions there are vehicle platform and system issues that need to be evaluated in order for the sensor system to be successfully integrated to a ground vehicle. These include discussion on sensor system merits, technology readiness level (TRL), MIL standards, mechanical, electrical, and data interfaces.

Does the sensor system generate automated threat messages with range, elevation, and azimuth of the shooter? How is the relocation of the threat determined? Will the system interface with the Remote Weapons Station? Is the system built on an open architecture and is the system delivered with a development kit for ease of integration and testing? These are all things which need to be addressed.

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Multispectral Detection and Location

Multispectral Defined

Multispectral is the use of multiple separate wavelength intervals. These wavelength intervals have characteristics that are wavelength dependent such as but not limited to atmospheric transmission and solar emission. The EM spectrum has been partitioned into general regions that have common characteristics, which are Ultraviolet (UV), Near-infrared (NIR), Visible, Mid-wave infrared (MWIR) and Long wave infrared (LWIR). Wavelength intervals can be in one or multiple EM regions. In figure 1 we show an example of a wavelength interval with good transmission through the atmosphere and low solar emission.

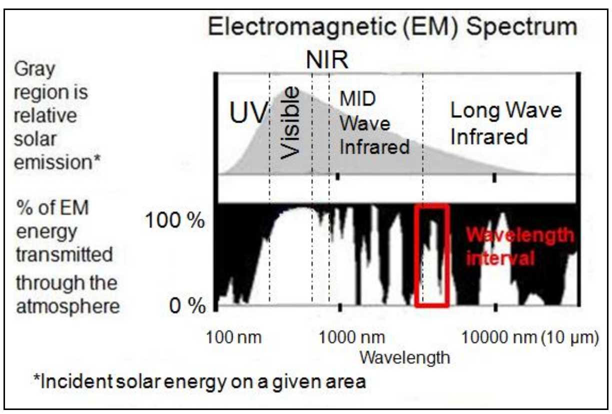

Figure 1: Electromagnetic spectrum wavelength dependent characteristics

Multispectral Methodology

Multispectral methodology is the exploitation of useful wavelength dependent characteristics for optimum results. This exploitation can be within one single or multiple EM regions and allows for best case scenario. Each EM region has its own sensor technology and the use of multiple regions in a multispectral methodology will generally increase exploitation complexity. Solar emission, which is wavelength dependent, is the leading cause of false detection which will be mitigated by the application of multispectral methodology. An example is shown in table 1 showing good and bad spectral characteristics.

Table 1: Electromagnetic spectrum regions. Green indicates "good" characteristics

Electromagnetic (EM) region	Transmission through medium	Sensor
Ultraviolet (UV)	Poor	**No solar emission observed**
Visible/ Near Infrared (NIR)	**Good**	**Low cost**, strong solar emission observed
Mid Wave Infrared (MWIR) and Long Wave Infrared (LWIR)	**Very Good**	Expensive, limited solar emission observed

The trade space, shown in figure 2, is comprised of the source, intervening medium, and sensor system. The overlap of possibilities may provide a solution for detection of a threat launch event. Trade space indicates all options for source, medium, and sensor system, and all are wavelength dependent. In the trade space the source is launch flash with the energy released or radiant intensity being wavelength dependent. Also, transmission through intervening medium such as obscurants and atmosphere are wavelength dependent. Finally, the spectral response of a sensor system is wavelength dependent. So applying the multispectral methodology to model source signatures we can compare possibilities with sensor spectral response to achieve the best scenario for detection.

As stated, when trade space crosses over, then we have a situation of detect/locate. In figure 1 we have different spectral regions which correspond to different locations on trade space. Spectral region affects source, medium transmission, and sensor system response. Solar irradiance is high in

NIR and not so high in UV, and tails off in longer wavelengths.

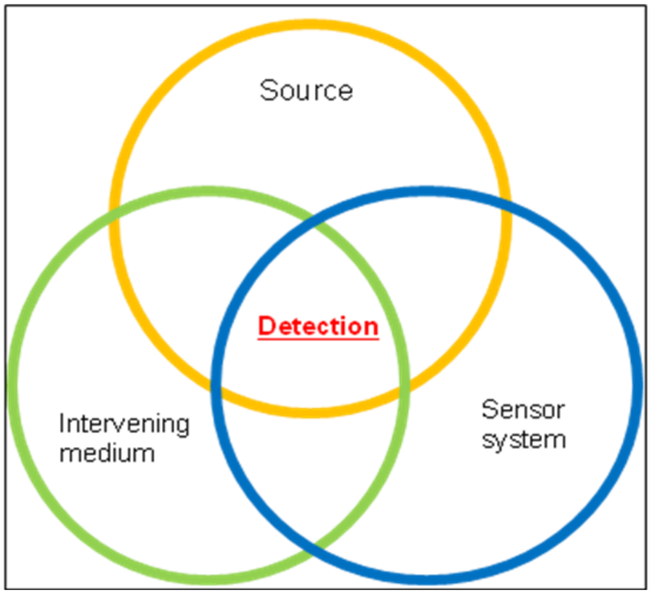

Figure 2: Trade space

Atmospheric transmission has sporadic good/bad transmission in MWIR and LWIR. Therefore, multispectral methodology combined over the trade space will give us optimum detect parameters.

Sensor System Integration

The detector, which is the instrumentation that allows for physical stimulus (e.g., light) to be monitored, captured, and converted into a more useful signal, has to be taken into consideration when trying to integrate it into a system of systems. We obtain optimum detector parameters from multispectral analysis. Since the detector and associated hardware, as shown in figure 3, is being integrated into an existing platform, the trade space dictates that the detector must be tailored so that it performs in accordance with the platform. We refer to the detector and associated hardware as the sensor system.

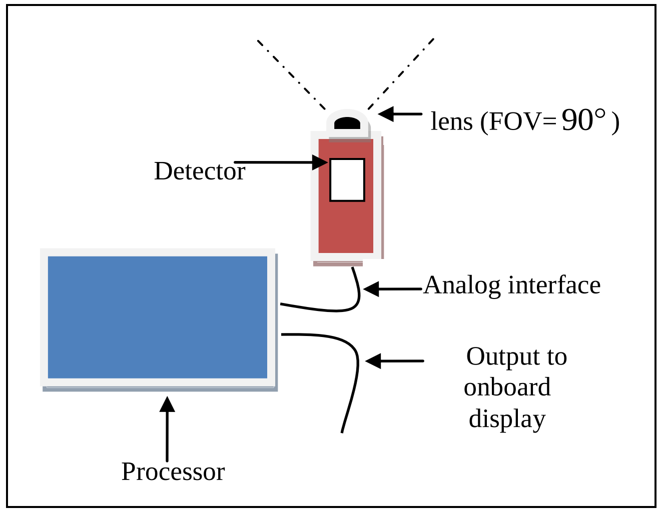

Figure 3: Example of sensor system layout

The basic requirement for this sensor system is to produce results instantaneously and therefore must allow for real-time processing. With real-time results come requirements that are more difficult to fulfill as opposed to systems that have to produce results post-event. To accomplish this, the processing speed must be increased in order to accommodate the additional load of image processing and data collection. Along those lines, an increase in data storage must be considered if the data is to be preserved. These memory allocations have to be taken into account since they are not only hardware constraints, but physical constraints on the overall system as well. Timing constraints can also sometimes be addressed by incorporating clever firmware and/or hardware devices into the system.

In Figure 3 the example of the sensor system is shown with the sensor module separate from the processor. In this way the image processing occurs separate from the senor unit with a dedicated high speed processing unit. This separation will allow the vehicle designers the freedom to consider appropriate placement of the sensor system on a mast with four sensors each covering a 90° field of view (FOV) yielding a full 360° FOV for the system. Of course, optical obstructions on the

vehicle need to be addressed in the case of EO/IR based sensors.

Typical parameters of a multispectral system are the processor module: 4 ft x 3 ft x 1 ft, weight 25lbs, and the sensor module: 3 ft x 1ft x 0.5ft with a weight of 5lbs. Positioning the sensor sytem on the vehicle will require passing the basic thermal, vibration and electromagnetic interference (EMI) requirements. This will require a minimum of 0° to 50° C operating temperature range, meeting the objectives of IAW 810F standard tests for vibration, and Mil-Std 461E for EMI testing. It is ideal if the total power draw is less than 5 amps and will operate in the 18-30 VDC range, as this would allow smaller gauge cable to be more easily routed to the sensor system on top of the mast and reduce susceptibility to EMI.

Since the sensor system will be integrated into an existing platform, the sensor must be able to communicate effectively in order to achieve successful threat detection. Given this parameter, the sensor system's output must be compatible and synchronized with that of the main platform. An ethernet based data interface to the sytem will allow for easier integration of the sytem management funtions and passing of the threat messages to the main system for threat detection and defeat as part of it's overall system architecture. A VICTORY[2] (Vehicular Integration for C4ISR/EW Interoperability) standard based data interface for the threat sensor system is currently under development that will describe an interface for data messaging between the sub-systems and the system data bus.

As various levels of readiness are addressed the available sensors can be evaluated based on each one's particular strengths and requirements.

REFERENCES

[1] Defense Update- International Online Defense Magazine 2004. "Countering the RPG threat"
[2] http://www.victory-standards.org/